Semi-annual Eos Contract Report -- Report #12
Period: July 1 - December 31, 1992
Remote Sensing Group (RSG), Optical Sciences Center (OSC) at the University of Arizona
Principal Investigator: P. N. Slater
Contract Number: NAS5-31717
Report compiled by: K. J. Thome

Introduction: This report contains eight sections. Each section presents a different aspect of work performed under our contract. If appropriate, each section covers five areas; task objective, work accomplished, data/analysis/interpretations, anticipated future actions, problems/corrective actions. The eight sections are: 1) Science team support activities; 2) Cross-calibration radiometer; 3) Reflectomobile; 4) Shortwave infrared (SWIR) radiometer; 5) Bi-directional reflectance distribution function (BRDF) meter; 6) Cary spectrophotometer; 7) Algorithm and code development; and 8) Field experiments.

Science Team Support Activities: This section refers to all work performed in support of MODIS and ASTER team activities as well as work performed for other sensor teams. Over the past six months this included the attendance at team and other related meetings, reviewing proposed descoping information, preparing recommendations for solutions to budget reductions, and the group's move to a new facility.

S. F. Biggar, J. M. Palmer, P. N. Slater, and K. J. Thome met with A. Kahle, S. Larson, D. Nichols, and C. Voge of the ASTER team on 29 July 1992 to discuss algorithm and software development. They also discussed the science computing facilities of the RSG. Slater attended the MODIS Internal Ground Support Equipment PDR at SBRC on August 18. Biggar, Palmer, and M. W. Smith attended the TIR Symposium/TIR Peer Review in Logan, Utah, September 14-17 where Smith presented a poster regarding the SWIR spectroradiometer. Biggar also attended the MODIS Calibration Peer Review on September 24 and the WGA of EOS Cal/Val Panel meeting at SBRC on September 25. He and Palmer attended the NewRAD (radiometry) conference in Baltimore October 5-7 and Biggar attended the MODIS PDR and Ocean's Group meetings in Santa Barbara October 21-25. He and Slater then attended the MODIS Calibration Working Group and MODIS Science Team meetings October 26-29. Biggar, Slater, and Thome attended the ASTER Science team meeting held in Tucson from November 10-12. Biggar gave a short presentation regarding the Third Annual Infrared Radiometric Sensor Calibration Symposium in September and the NewRAD conference he attended the previous month. Slater spoke on the progress of the ASTER Calibration Working Group and the MODIS Science Team Calibration Panel meetings he attended the previous month. Slater and Thome also attended the ASTER Software Development Workshop held later that same week.

Biggar attended the Infrared and Visible Optical Sensors subgroup of the Working Group for Calibration and Validation of CEOS meeting at Camp Springs, Maryland on November 30 and December 1.

Biggar and Slater reviewed the materials presented at the MODIS Internal Ground Support Equipment PDR to determine the RSG's preflight cross-calibration responsibilities. They also reviewed an SBRC internal memo describing the relationship between changes in radiometric accuracy, registration, and MTF for MODIS. Biggar, Slater, and Thome reviewed the descoping proposed for MODIS and the proposed descoping of ASTER and MODIS products. Thome faxed comments regarding the revised ASTER product list to team leader Kahle. Slater faxed responses to suggested MODIS sensor descopes to team leader V. V. Salomonson.

Critical changes to MODIS calibration to avoid cost overruns were discussed at the MODIS Calibration Working Group Science Team meetings. Slater summarized these discussions in the final plenary session. In brief, the recommendations are: 1. the Spectro-Radiometric Calibration Assembly (SRCA) must be retained and be of improved stability, it will be used as the only thermal/vacuum test instrument for some system characterizations, 2. the Solar Diffuser Stability Monitor (SDSM) and solar diffuser must also be retained. Cost savings will be effected by simplifying the Ground Support Equipment (GSE), eliminating one GSE calibrator system and reducing the scope of thermal/vacuum tests.

Biggar, Slater, and Thome critically reviewed the MODIS Spectral Sensitivity Study, MODIS Mission Calibration Plan and MODIS Level-1B Calibration Algorithm Plan. They forwarded their comments to J. Barker and B. Guenther. One result from discussions following this review was that the RSG will review MCST documents before these documents are distributed for review to the MODIS Science Team.

Lastly, the group moved into a new facility in mid-October. As part of the move, our local ethernet network was connected to the University of Arizona campus ethernet giving us access to internet. Our new address as well as email addresses for several members of the group are given as an appendix to this report.

Cross-Calibration Radiometer: The objective of this project is to design and build a 400 to 900 nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will provide an independent calibration and cross-calibration of radiance sources used by Phase C/D contractors. Biggar designed the radiometer with three silicon detectors in a "trap" configuration. Spectral selection is through interference filters selected by manually turning a filter wheel. Two precision apertures determine the throughput. Heating the detector assembly, filters, apertures, and amplifier to a stabilized temperature a few degrees above ambient provides thermal control of the system. A commercial datalogger will digitize the amplifier output and ancillary information such as detector temperature. This datalogger will send the serial digital data to a MS-DOS compatible computer. The entire radiometer consists of the head with filter wheel, the electronics/power supply package, connecting cables, datalogger, and computer.

Biggar has completed assembling the electronics/power supply module and wiring the detector assembly. The temperature control system for the detector and second aperture is operational. He also began developing the data acquisition software. Plans are to make preliminary SNR and other measurements after filter delivery with the radiometer in its current form. Biggar will also complete development of data acquisition software and characterize the interference filters. Our "black" room/lab, which will be used for further SNR and calibration studies, is currently being reassembled. We have encountered problems with the "diffuse" black paint we recently applied to this room. Measurements indicate the paint has an unacceptably high specular reflectance component throughout most of the visible and near-infrared and we are currently searching for a remedy to this problem.

Reflectomobile: The task objective is to design a vehicle and instrument package to perform surface reflectance measurements more accurately and repeatably with only one person. In the past, people have carried yokes which extend the radiometers away from the walker's body to reduce shadow and other problems. This method requires the involvement of at least three people, takes about 40 minutes to cover a 0.02 km^2 site, and depends on the ability of the walker to orient the radiometer correctly. We have designed and constructed the reflectomobile based on a tetrahedral space frame attached to a trailer, with a vehicle towing the trailer across the study site to collect data.

D. I. Gellman had the exposed steel parts galvanized, and he reinforced the trailer's frame at the space frame mounting points using steel backing plates and brackets. Gellman also constructed an assembly for transporting and storing the parts of the reflectomobile on the trailer. After the initial test of the reflectomobile at White Sands Missile Range, it was decided to shorten the trailer axle to allow the wheels to fit better within the tow vehicle's tire tracks. This also entailed having the fenders moved inward. To make data collection more reliable, the Paravant computers were sent back to the manufacturer and rewired to allow us to connect an external DC power source, and a battery/car cigarette lighter adapter was purchased. Gellman continued work on software to retrieve surface reflectance from reflectomobile data and enhanced the data collection software to display real-time graphs of the data collected. We also obtained a spare tire for the trailer and mounted it to the trailer.

We conducted two field experiments at White Sands during the reporting period. These experiments were used to refine the data collection procedures and for comparisons with other reflectance retrieval techniques. Comparisons with the yoke-based method yielded reflectance within 1% of one another. The standard deviations were notably higher for the reflectomobile reflectance, but it was later determined that this was due to differences in processing of the data. Planned comparisons with aircraft-based reflectance measurements were thwarted by clouds. During the second field experiment, reflectance was measured over the target site twice within a one-hour period. (Note that this is about the time required to make only one pass across the site with the yoke-based method.) Results from this experiment indicate the measurements are quite repeatable as the reflectance between the two runs differed by less than a few percent for most of the transects.

Differences for one of the transects were noticeably higher than the others. This was most likely due to shadows being present within the field of view of the instrument. The instrument can be positioned to remove these effects, but we determined the mount used to do this must be improved for better stability. Other problems encountered are results of shortening the trailer axle. First, the new location of the fenders interfered with the space frame assembly's mount to the trailer. Gellman resolved this problem by moving the mount point toward the center of the trailer by using an aluminum block. This solution also reduced the transverse tilt of the space frame. The second problem was that the original tow vehicle, an Isuzu Trooper, was retired from service by the university's garage. A full-size pickup truck is now the tow vehicle. This truck has both a wider wheel base and higher trailer hitch mount point than the Isuzu. The problem with the width of the new truck may be solved by putting the original axle back on the trailer. The higher hitch mount gives the trailer, and thus the instruments, a noticeable tilt. To remove this tilt, a larger adjustable drop hitch or a method for rotating the instruments will be used.

Besides adjusting the instrument mount, Gellman will finish code for processing the data to obtain reflectance. He will also develop a mount to accept other instruments such as our SWIR spectroradiometer and create a method for geo-locating the reflectance data within the target area. We will also attempt to determine the uncertainty in the retrieved reflectance by making several measurement runs over the site in rapid succession.

SWIR spectroradiometer: The objective of this task is to design and construct an instrument to measure surface reflectance in the SWIR region of the spectrum. When our contract began, M. W. Smith had already designed and built the prototype. He continued working on the SWIR spectroradiometer by adding shielding, buffering, and filtering to the A/D conversion electronics which only slightly reduced the electronic noise. The manufacturer repaired the display of the Paravant computer used for data collection. To maintain a constant and repeatable SNR, the system will be operated at a constant temperature of 298 K, using heating or cooling as necessary. Smith installed a thermo-electric cooler and other control/driver electronics for this purpose. He also installed anti-reflection (A/R) coated versions of the cold filter and dewar window, as well as cold stops for the dewar. Smith discovered the A/R coating on the silicon filter was improperly applied by the vendor. He removed this coating and sent the filter for recoating. The SNR increased by a factor of two with the new A/R coating. Smith characterized the non-linear output of the SWIR spectroradiometer, collected data for an absolute radiometric calibration of the instrument, and measured the polarization sensitivity of the instrument. Smith presented a paper on the instrument at the SPIE meeting in San Diego, July 19-24 and, in November, successfully defended his PhD dissertation titled "Design, construction, and calibration of a portable short wave infrared spectroradiometer."

The instrument had its initial field test at White Sands Missile Range in December. This test was part of the SPOT-2 and JERS-1 calibration field trip discussed later. The spectroradiometer was tested in a helicopter environment and on the ground in a backpack/yoke configuration. A mount for the instrument on the reflectomobile must still be developed. It also became apparent that a more reliable data collection method must be developed. This problem became apparent when both the regular and backup batteries for the data collection computer failed and all of the instrument control software was erased because it was stored in volatile RAM. The computer will be checked and repaired and a backup computer will be obtained. Data from this recent trip has yet to be processed and will be presented in a future report.

As mentioned, other future work includes creating a mount for the instrument on the reflectomobile. This will most likely be done by acquiring a longer fiber optic cable for the collector optics. The spectroradiometer will also undergo further field testing and comparisons with other instrumentation. The reflectance retrieval software will be developed and a user manual written.

BRDF Meter: The objective for this task is to design and construct a device and software for measuring the directional reflectance and inferring the bi-directional reflectance distribution function of the ground. The basic design incorporates a fisheye lens and a CCD-array detector. The objective of this six-month period was to order the detector array and interference filters and make preliminary measurements to determine the exposures and develop a method of calibration. The data collection, storage, and processing software and facilities were to be investigated, as was a method for automating the system.

M. R. Brownlee investigated possible detector systems for the BRDF meter. Biggar, Brownlee, and Slater met with representatives from Photometrics to discuss a custom-made CCD system. A Photometrics CCD array/camera system and accompanying data acquisition software were selected and ordered based on functionality and cost. This detector system increases the digitization from eight to 14 bits, has a cooled CCD array to maintain the desired SNR, and a large size array that completely covers the image formed by the fisheye lens. These features will both improve the accuracy as well as simplify the automation of the instrument.

Brownlee also investigated methods for automating the BRDF meter. The filter wheel will be motorized and controlled by the CCD controller host computer. A motorized mount will maintain instrument alignment with the solar principal plane and shutter speed will be automatically adjusted for optimal data collection. These automation features will be added after the prototype instrument has been constructed and the concept of the instrument proven.

Future work will consist of integrating the detector array/camera into appropriate mounts and obtaining the interference filters for the system. Brownlee will devise a calibration method and determine the facilities necessary for this method. She will begin calibrating the system as well as start image collection and processing software development.

Cary Spectrophotometer: The objective of this project is to refurbish a Cary 14 spectrophotometer for use in the laboratory. Palmer continued work on the project by redesigning the output optics to accommodate the anticipated integrating sphere that will be used for diffuse spectral reflectance measurements. The output beam will be approximately 25 mm in diameter, maintaining sufficient beam radiance for full-aperture testing in collimated light for our filters. Palmer ordered the parts for the output optics. The assembly of the detector, including the 1" integrating sphere and Si and Ge detectors, is nearing completion. Palmer determined that a heat sink for the TE cooler on the Ge detector will be necessary. He also completed the initial wavelength calibration and SNR tests on the Si and Ge detectors over the 400 to 1600 nm spectral range with a slit width of 250 micrometers. From these tests Palmer determined that the SNR is sufficient enough with an open beam to allow a relatively inexpensive preamplifier interface and no chopper is required unless we try to measure high optical densities (>3). It is anticipated that construction of the spectrophotometer will be completed during the next six-month reporting period.

Algorithm and Code Development: This section is broken into two parts. The first part discusses work relating to the thermal infrared (TIR) portion of the spectrum. The second covers the algorithms and code used in the visible and NIR. In addition, Thome completed rough drafts of the algorithm survey and SCF block diagram requested by D. Nichols and C. Voge of ASTER. Data flow diagrams, to be used for documentation and system maintenance, were started for the software package. Thome wrote drafts of the Algorithm Theoretical Basis Document and the Algorithm Development and Test Plan for the ASTER Level 2B products, surface radiance and surface reflectance. He also developed a revised software development schedule to be included with these documents. The ASTER Level 1B special products documents for both ASTER and MODIS were started.

TIR: Currently, several algorithms exist to perform work in the TIR portion of the spectrum. The task is then to determine which of these algorithms best fits the current problem. Palmer continued his search of the literature of these methods and is in the process of determining which is the most appropriate. Two infrared thermometers (IRT) were received, checked and found to work adequately. Data were obtained from the manufacturer regarding the spectral responsivity of the IRTs. Palmer measured the angular FOV at approximately 15 degrees FWHM. The software required to run the IRTs was developed. One program was developed to test the interface and functionality. The second operates the IRT and logs time-stamped data to a file. Palmer initially tested both programs tested on an office PC. A Zeos Pocket PC was received for operating one of the IRTs. Initial tests of the computer and IRT were positive, but problems have since surfaced such that the pocket computer no longer works for uploading and downloading. Lastly, data were collected during an August White Sands trip for calibration of the thermal band on Landsat-5. Palmer has begun processing the ground data from this trip but is still waiting for the satellite data to be delivered from Eosat.

Visible and NIR: Currently, several algorithms exist to perform work in this portion of the spectrum. The RSG has applied these algorithms as FORTRAN programs which are neither user friendly nor efficiently linked together into a single package. The task objective is to convert these existing codes into ANSI standard C in a user-friendly package with rules-based decision making in the package.

As part of this project, Brownlee processed solar radiometer data and began developing a data storage methodology for the results. These results will be used to determine temporal changes in instrument response as well. Brownlee and Thome will use these data to test the rules-based algorithms for processing solar radiometer data and as a basis for developing test data sets for the software packages.

Thome continued adding the water vapor retrieval algorithm to the Langley method program but then modified the software development approach because of new responsibilities to ASTER. The group has been requested to develop algorithms/software for retrieving surface radiances and reflectance from ASTER. The delivery of this software to a DAAC facility requires a more rigorous development procedure as outlined by the ASTER team. This also requires delivery of a Beta version of the software to the ASTER team leader at the end of the second quarter of 1993.

The only problems encountered during the reporting period were in changing focus for the software development. The software package will now be developed from the algorithms used by the group not the software. This will produce a more coherent and easier to maintain package.

Thus future work will concentrate on data flow diagrams, data dictionaries, and pseudo-code development for the package as part of a structured systems design approach. Efforts will focus on developing the Beta version of software for the surface radiance and reflectance retrievals. This will cause the development of the Beta version for the special products software for both ASTER and MODIS to slip by approximately three months. As the special products software is not to reside at the DAAC, and the schedule is to still complete the Version 2 package by launch, no problems are anticipated due to this slippage.

System administration work was performed by H. He, who also continued developing software to read satellite tape images onto the UNIX-based-Sun network. She modified existing software to enable reading of the new Landsat tape format for both Level 0 and Level 1 data. D. I. Gellman continued work on software to retrieve surface reflectance from reflectomobile data. Gellman also began work on AVHRR calibrations with reference to SPOT imagery. This is an important precursor to inflight cross-calibration studies between ASTER, MISR, and MODIS.

Field Experiments: The objectives of the field experiments are to test new equipment, determine needed improvements, test retrieval algorithms and code, and monitor existing satellites in much the same way as we shall for Eos sensors. During the six-month period, the RSG made two trips to White Sands Missile Range, an equipment calibration trip to Mt. Lemmon, and a trip to Maricopa Agricultural Center. The group also provided data support to S. Soorooshian's EOS interdisciplinary project in the Walnut Gulch watershed in Arizona.

Gellman and Thome travelled to Maricopa Agricultural Center to collect atmospheric data in conjunction with SPOT-2 and Landsat-5 overpasses on July 26, while representatives of the USDA Water Conservation Lab collected surface reflectance measurements of the ground targets. The data from this trip were processed, and the results provided to the Water Conservation Lab.

Gellman and Slater travelled to White Sands on August 12, to perform tests of the reflectomobile and determine the transects of the site to be used for the calibrations. On August 14, Brownlee, Palmer, and Thome arrived at White Sands accompanied by M. S. Moran of the Agricultural Research Service and A. F. Rahman a graduate student from the Soil and Water Science Department at the University of Arizona. This was the initial test of the reflectomobile at White Sands, and the first time data from the reflectomobile and the yoke-based instruments were collected at the same time. The results from this comparison are quite favorable with differences in retrieved reflectance well within the uncertainties of the instrumentation. Thermal infrared data were also collected over the site and Palmer is using these data to calibrate the thermal band for Landsat-5 TM.

A trip to White Sands was also made from December 11-15 to try to obtain data for calibrating NOAA-11 AVHRR, SPOT-2 HRV, and JERS-1 (now called Fuyo-1) OPS. Gellman,

C. L. Grotbeck, and Thome travelled early to test the reflectomobile and collect data for the NOAA-11 overpass. Clouds, high winds, and rain prevented the collection of useful data for this satellite. Biggar and Smith joined the others on December 14. Successful data were collected on this day for SPOT-2 overpass. These data included two successive runs of the reflectomobile to test the repeatability of the reflectance measurements. The results of this experiment are discussed in detail in a previous section. Unfortunately, clouds on the next day hampered the collection of useful data for SPOT-2 and Fuyo-1, but several pieces of equipment were flown by helicopter over the site. This included the SWIR spectroradiometer, making its initial field test, a video camera, and still camera. The photos will allow us to make a more detailed study of our site and the data collected on the SWIR spectroradiometer will be used to check its performance in a hostile-vibration environment.

Gellman updated data reduction software and reduced all White Sands data sets, except the December data. He also processed data collected at Edwards Air Force Base the end of May and Maricopa Agricultural Center in July. Gellman began work on a calibration of NOAA-11 and -12 AVHRRs using SPOT-2 and data collected at White Sands in November 1991 and August 1992.

Thome, accompanied by groups from the Atmospheric Sciences and Electrical and Computer Engineering departments at the university, travelled to Mt. Lemmon, Arizona to calibrate the group's solar radiometers. Gellman, Grotbeck, Smith, and Thome all made trips to the Walnut Gulch watershed to collect atmospheric data as part of an ongoing project there and in support of S. Sorooshian's Interdisciplinary Investigation titled "Hydrologic Cycle and Climate Processes in Arid and Semi-Arid Lands." A future trip to White Sands is planned for late March or early April. This trip will include several French scientists, and will be used to test equipment and calibrate SPOT-2 HRV and JERS-1 OPS.

Appendix: The following is the new address for the Remote Sensing Group::

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Internet Addresses for several members of the group are as follows:

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Access to other members of the group may be obtained through these addresses as well. Phone numbers of all members remain unchanged.